TITLE OF THE INVENTION

Transmitter For Tire Condition Monitoring Apparatus And Tire Condition Monitoring Apparatus

BACKGROUND OF THE INVENTION

The present invention relates to a wireless-type tire condition monitoring apparatus and a transmitter for the tire condition monitoring apparatus which enable checking of tire conditions, including the air pressure in a tire, from the interior of a vehicle.

Japanese Laid-Open Patent Publication No. 2001-56263 discloses a wireless-type tire condition monitoring apparatus for checking the conditions of a plurality of tires mounted on a vehicle from the interior of the vehicle. The monitoring apparatus has a plurality of transmitters respectively attached to the tires, a receiver mounted on the body of the vehicle, and a display device for informing the driver of the vehicle of the air pressure conditions of the tires. Each transmitter measures tire conditions, including the internal air pressure and the internal temperature of the corresponding tire, and transmits data indicating the measured tire conditions to an electric wave receiving device. The receiver has a plurality of receiving antennas, a synthesizer and the receiving device. The synthesizer selectively outputs to the electric wave receiving device the maximum voltages induced in each receiving antenna. Consequently, the receiver can stably receive a signal transmitted from each transmitter.

In general, the temperature in tires changes under the influence of outside air temperature, direct rays of the sun, heat generated by traveling, etc. The performance of the transmitter constituted by semiconductor electronic components depends on temperature. More specifically, the transmission power of the transmitter decreases as the internal tire temperature rises.

The transmitter rotates together with the tire when the vehicle travels. Depending on the position of the transmitter at the time of transmission, there is a possibility of the receiver being unable to receive data from the transmitter. When the transmission output of the transmitter is reduced, the reception probability, i.e., the probability of data being received by the receiver, is also reduced. According to an experiment, the intensity of the electric field at the receiving antenna decreases by 1 dBμV/m each increase of the internal tire temperature by forty degrees Centigrade.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a transmitter for a tire condition monitoring apparatus and a tire condition monitoring apparatus designed by considering temperature dependence.

To achieve the above-described object, the present invention provides a transmitter for a tire condition monitoring apparatus located in the tire of a vehicle. The transmitter includes a measurement device, a transmission device and a transmission controller. The measurement device measures the condition of the tire. The measured condition of the tire includes an internal temperature of the tire. The transmission device performs wireless communication of data indicating the condition of the tire measured by the measurement device. The transmission controller controls the transmission device in accordance with an operating mode selected from a normal mode, in which data transmission is performed a predetermined number of times in a cycle of a predetermined length of time, and a temperature compensation mode, in which data transmission is performed a number of times greater than the predetermined number of times in the same cycle. The transmission controller determines whether to shift from the current one of the operating modes to the other operating mode by comparing the measured internal temperature of the tire with a predetermined threshold temperature.

The present invention provides another transmitter for a tire condition monitoring apparatus located in the tire of a vehicle. The transmitter includes a measurement device, a transmission device and a transmission controller. The measurement device measures the condition of the tire. The measured condition of the tire includes an internal temperature of the tire. The transmission device performs wireless communication of data indicating the

condition of the tire measured by the measurement device. The transmission controller controls the transmission device in accordance with an operating mode selected from a normal mode in which data transmission is performed at first time intervals and a temperature compensation mode in which data transmission is performed at second time intervals shorter than the first time intervals. The transmission controller determines whether to shift from the current one of the operating modes to the other operating mode by comparing the measured internal temperature of the tire with a predetermined threshold temperature.

The present invention also provides a tire condition monitoring apparatus located in a tire of a vehicle. The tire condition monitoring apparatus has a transmitter and a receiver. The receiver receives data transmitted from the transmitter and which processes the received data. The transmitter includes a measurement device, a transmission device and a transmission controller. The measurement device measures the condition of the tire. The measured condition of the tire includes an internal temperature of the tire. The transmission device performs wireless communication of data indicating the condition of the tire measured by the measurement device. The transmission controller controls the transmission device in accordance with an operating mode selected from a normal mode, in which data transmission is performed a predetermined number of times in a cycle of a predetermined length of time, and a temperature compensation mode, in which data transmission is performed a number of times greater than the predetermined number of times in the same cycle. The transmission controller selects the operating mode by comparing the measured internal temperature of the tire with a predetermined threshold temperature.

The present invention provides another tire condition monitoring apparatus located in a tire of a vehicle. The tire condition monitoring apparatus has a transmitter and a receiver.

The receiver receives data transmitted from the transmitter and which processes the received data. The transmitter includes a measurement device, a transmission device and a transmission controller. The measurement device measures the condition of the tire. The measured condition of the tire includes an internal temperature of the tire. The transmission device performs wireless communication of data indicating the condition of the tire measured by the measurement device. The transmission controller controls the transmission device in accordance with an operating mode selected from a normal mode in which data transmission is performed at first time intervals and a temperature compensation mode in which data transmission is performed at second time intervals shorter than the first time intervals. The transmission controller selects the operating mode by comparing the measured internal temperature of the tire with a predetermined threshold temperature.

Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

Fig. 1 is a block diagram showing a tire condition monitoring apparatus in an embodiment of the present invention;

Fig. 2 is a block diagram of a transmitter provided in the monitoring apparatus shown in **Fig. 1**;

Fig. 3 is a timing chart for explaining the operation of the transmitter;

Fig. 4 is a block diagram showing a receiver provided in the monitoring apparatus shown in **Fig. 1**; and

Fig. 5 is a flowchart showing the transmitting operation of the transmitting circuit based on data on temperature measured by a temperature sensor.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An embodiment of the present invention in which the present invention is implemented will be described with reference to **Figs. 1 to 5**.

As shown in **Fig. 1**, a tire condition monitoring apparatus **1** has transmitters **30** respectively provided on four tires **20** of a vehicle **10**, and one receiver **40** provided on the vehicle body **11** of the vehicle **10**.

Each transmitter **30** is fixed on a wheel **21** while being positioned inside the corresponding tire **20**. Each transmitter **30** measures the conditions of the corresponding tire **20**, i.e., the air pressure and temperature in the corresponding tire **20**, to obtain data including air pressure data and temperature data, and transmits the data to the receiver **40** by wireless communication.

The receiver **40** is mounted in a predetermined place on the vehicle body **11** and operates, for example, by power from a battery (not shown) of the vehicle **10**. The receiver **40** has one receiving antenna **41**, which is connected to the receiver **40** by a cable **42**. The receiver **40** receives through the receiving antenna **41** a signal transmitted from each transmitter **30**.

A display device **50** is placed in such an area as to be visible from the driver of the vehicle **10**, for example, in the interior of the vehicle. The display device **50** is connected to the receiver **40** by a cable **43**.

As shown in **Fig. 2**, each transmitter **30** has a transmission controller **31** constituted by a microcomputer or the like. The transmission controller **31** has, for example, a central processing unit (CPU), a read-only memory (ROM) and a random-access memory (RAM).

In an internal memory, e.g., the ROM of the transmission controller **31**, unique ID codes are registered. The ID codes are used for identification of the four transmitters **30**.

A pressure sensor **32** measures the air pressure in the tire **20** to obtain air pressure data, and outputs the air pressure data to the transmission controller **31**. A temperature sensor **33** measures the temperature in the tire **20** to obtain temperature data, and outputs the temperature data to the transmission controller **31**. In this embodiment, each of the pressure sensor **32** and the temperature sensor **33** functions as a measuring device.

The transmission controller **31** outputs to a transmitting circuit **34** the input air pressure data and temperature data and the ID codes registered therein. The transmitting circuit **34** transmits the data including the air pressure data, the temperature data and the ID codes to the receiver **40** by wireless communication through a transmitting antenna **35**. The transmitter **30** has a battery **36**. The transmitter **30** operates by power from the battery **36**.

As shown in **Fig. 3**, the transmission controller **31** controls the pressure sensor **32** and the temperature sensor **33** to perform measuring operations at measurement time intervals **t1** set in advance (at intervals of 15 seconds in this embodiment). A time **t2** shown in **Fig. 3** is a measuring operation time, i.e., a period of time from the moment at which the pressure sensor **32** and the temperature sensor **33** start measuring to the moment at which processing of data obtained by measuring is completed by the transmission controller **31**.

The transmission controller **31** counts the number of measurements made by the pressure sensor **32** and the temperature sensor **33**. Each time a predetermined number of measurements (forty measurements in this embodiment) is reached, the transmission controller **31** controls the transmitting circuit **34** to perform the transmitting operation. In this embodiment, the measurement time interval **t1** of measurements made by the pressure

sensor **32** and the temperature sensor **33** is ordinarily determined to be fifteen seconds. Accordingly, the transmission controller **31** controls the transmitting circuit **34** to perform the transmitting operation at transmission time intervals set in advance, e.g., intervals of ten minutes (15 sec. × 40), as shown in **Fig. 3**. A time **t3** shown in **Fig. 3** is a transmitting operation time, i.e., a period of time during which the transmitting circuit **34** performs the transmitting operation for transmission to the receiver **40**. Therefore, the transmitter **30** is in a sleep state such that substantially no power from the battery **36** is consumed during the time period other than the above-described measuring operation time **t2** and the transmitting operation time **t3**.

The measurement time interval **t1** and the transmission time interval **t4** are determined, for example, by considering the capacity of the battery **36**, the power consumption of the transmitter **30**, and the measuring operation time **t2** and the transmitting operation time **t3** of the transmitter **30**. For instance, it has been confirmed that the life of the battery **36** is 10 years or longer in a case where the battery **36** used has a capacity of 1000 mAh, and where the measurement time interval **t1** is fifteen seconds and the transmission time interval **t4** is ten minutes.

The transmission controller **31** controls the transmitting circuit **34** to perform the transmitting operation at the above-described constant transmission time intervals **t4** (first time intervals) (in a normal mode). However, when the transmission controller **31** determines on the basis of temperature data from the temperature sensor **33** that a mode change condition set in advance is satisfied, it effects a transition from the normal mode to a temperature compensation mode. The mode change condition is an increase in temperature in the tire **20**.

In a temperature compensation mode, the transmission controller **31** controls the transmitting circuit **34** to perform the transmitting operation at time intervals (second time intervals) shorter than the transmission time interval **t4** in the normal mode and equal to or longer than the measurement time interval **t1**. However, even when a transition to a temperature compensation mode is made, the measurement time interval **t1** of measurements made by the pressure sensor **32** and the temperature sensor **33** is not changed.

In this embodiment, the operating mode of the transmitter **30** is changed to a first temperature compensation mode when the value of data of the temperature measured by the temperature sensor **33** is equal to or higher than a predetermined first threshold temperature (e.g., forty degrees C) and lower than a second threshold temperature (e.g., eighty degrees C) while the transmitter **30** is operating in the normal mode.

When the value of data of the temperature measured by the temperature sensor **33** becomes equal to or higher than the predetermined second threshold temperature (e.g., eighty degrees C), the operating mode of the transmitter **30** is changed to a second temperature compensation mode. In this embodiment, when the value of data of the temperature measured by the temperature sensor **33** is lower than the predetermined first threshold temperature (e.g., forty degrees C), the operating mode of the transmitter **30** is changed to the normal mode.

Thus, the transmitter **30** operates in one of the normal mode, the first temperature compensation mode and the second temperature compensation mode by comparing the value of data of the temperature measured by the temperature sensor **33** with the predetermined threshold temperatures.

As shown in **Fig. 4**, the receiver **40** has a receiving circuit **45** and a reception controller **44** for processing data received through the receiving antenna **41**. The reception controller **44** constituted by a microcomputer or the like has, for example, a CPU, a ROM and a RAM. The receiving circuit **45** receives data transmitted from each transmitter **30** through the receiving antenna **41**. The receiving circuit **45** demodulates and decodes the received data and supplies the demodulated data to the reception controller **44**.

The reception controller **44** determines, on the basis of the received data, the air pressure and the temperature in the tire **20** corresponding to the transmitter **30** that has transmitted the data. The reception controller **44** controls the display device **50** to display the data on the air pressure and the temperature. In particular, when an air pressure abnormality occurs in the tire **20**, the reception controller **44** controls the display device **50** to display a warning. The receiver **40** starts up, for example, by switching on the key switch (not shown) of the vehicle **10**.

The transmitting operation of the transmitting circuit **34** based on data on the temperature measured by the temperature sensor **33** will be described with reference to the flowchart of **Fig. 5**.

In step **S1**, the transmission controller **31** controls the temperature sensor **33** to perform the measuring operation at measurement time intervals **t1** (intervals of fifteen seconds in this embodiment). The temperature sensor **33** measures the temperature in the tire **20** to obtain data on the temperature and outputs the temperature data to the transmission controller **31**. The transmission controller **31** advances the process to step **S2**.

In step **S2**, the transmission controller **31** makes a determination as to whether or not the value of data of the temperature in the tire **20** measured by the temperature sensor **33** is

lower than the first threshold temperature (e.g., forty degrees C). If YES in step **S2**, that is, the value of data on the temperature in the tire **20** is lower than the first threshold temperature (e.g., forty degrees C), the transmission controller **31** advances the process to step **S3**. In step **S3**, the transmission controller **31** controls the transmitting circuit **34** to perform the transmitting operation once every ten minutes (normal mode).

If NO in step **S2**, that is, the value of data on the temperature in the tire **20** is not lower than the first threshold temperature (e.g., forty degrees C), the transmission controller **31** advances the process to step **S4**. In step **S4**, the transmission controller **31** makes a determination as to whether or not the value of data on the temperature in the tire **20** measured by the temperature sensor **33** is equal to or higher than the first threshold temperature (e.g., forty degrees C) and lower than the second threshold temperature (e.g., eighty degrees C). If YES in step **S4**, that is, the value of data on the temperature in the tire **20** is equal to or higher than the first threshold temperature (e.g., forty degrees C) and lower than the second threshold temperature (e.g., eighty degrees C), the transmission controller **31** advances the process to step **S5**. In step **S5**, the transmission controller **31** controls the transmitting circuit **34** to perform the transmitting operation twice every ten minutes (at the second time intervals) (first temperature compensation mode), more specifically once every five minutes (= 10 min./2).

If NO in step **S4**, that is, the value of data on the temperature in the tire **20** is not lower than the second threshold temperature (e.g., eighty degrees C), the transmission controller **31** advances the process to step **S6**. In step **S6**, the transmission controller **31** controls the transmitting circuit **34** perform the transmitting operation thrice every ten minutes (at third

time intervals) (second temperature compensation mode), more specifically once every 10/3 minutes.

This embodiment has advantages as described below.

The transmission controller **31** compares the value of data on the temperature in the tire **20** measured by the temperature sensor **33** and determines the number of times the transmitting circuit **34** performs the transmitting operation per each ten minute cycle. For example, when the temperature in the tire **20** rises to become equal to or higher than a threshold temperature, the number of times the transmitting circuit **34** performs the transmitting operation per each ten minute cycle is increased. The possibility that the receiver **40** fails to receive data from the transmitter **30**, depending on the position of the transmitter **30** at the time of transmission, is thereby reduced. In other words, the reduction in the reception probability of the receiver **40** is limited even when the transmission power of the transmitter **30** is reduced due to an increase in the temperature in the tire **20**. Thus, it is possible to provide the transmitter **30** designed by considering the temperature dependence.

The transmission time interval in the first or second temperature compensation mode (in the case of performing transmission once every five minutes or every 10/3 minutes) is shorter than the transmission time interval in the normal mode (in the case of performing transmission once every ten minutes). Also, the transmission time interval in the second temperature compensation mode (in the case of performing transmission once every 10/3 minutes) is shorter than the transmission time interval in the first temperature compensation mode (in the case of performing transmission once every five minutes). Therefore, the possibility of the distance between the transmitter **30** and the receiving antenna **41** being shorter than a predetermined distance is increased and the reduction in the reception

probability of the receiver **40** can be limited even when the transmission output of the transmitter **30** is reduced due to an increase in the temperature in the tire **20**. Thus, it is possible to provide the transmitter **30** designed by considering the temperature dependence.

The above-described embodiment can also be implemented by being modified as described below.

It should be apparent to those skilled in the art that the present invention may be embodied in many other specific forms without departing from the spirit or scope of the invention. Particularly, it should be understood that the invention may be embodied in the following forms.

The method of controlling the transmitting circuit **34** to perform the transmitting operation twice as often per each ten minute cycle in the first temperature compensation mode may be modified such that the transmitting operation is continuously performed, rather than twice as often per each ten minute cycle. That is, the transmitting operation may be performed all the time rather than being performed twice as often per each ten minute cycle. The same can also be said with respect to the second temperature compensation mode.

When the temperature in the tire **20** measured by the temperature sensor **33** is equal to or higher than a predetermined threshold temperature (e.g., one hundred and twenty degrees C), data indicating that the temperature in the tire **20** is abnormally high may be transmitted to the receiver **40**.

The vehicle in which the apparatus of the present invention is used is not limited to four-wheel vehicles. The above-described embodiment may be applied to two-wheel vehicles, such as bicycles and motor cycles, multi-wheel vehicles, such as buses and trailers, vehicles for industrial use having tires **20** (e.g., forklift trucks), etc.

The present examples and embodiments are to be considered as illustrative and not restrictive and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalence of the appended claims.